Morgan, Scott; Davies, Christopher; Thomas, Christian


Summary: The control of stationary convective instabilities in the rotating disk boundary layer via a time-periodic modulation of the disk rotation rate is investigated. The configuration provides an archetypal example of a three-dimensional temporally periodic boundary layer, encompassing both the von Kármán and Stokes boundary layers. A velocity-vorticity formulation of the governing perturbation equations is deployed, together with a numerical procedure that utilises the Chebyshev-tau method. Floquet theory is used to determine the linear stability properties of these time-periodic flows. The addition of a time-periodic modulation to the otherwise steady disk rotation rate establishes a stabilising effect. In particular, for a broad range of modulation frequencies, the growth of the stationary convective instabilities is suppressed and the critical Reynolds number for the onset of both the cross-flow and Coriolis instabilities is raised to larger values than that found for the steady disk without modulation. An energy analysis is undertaken, where it is demonstrated that time-periodic modulation induces a reduction in the Reynolds stress energy production and an increase in the viscous dissipation across the boundary layer. Comparisons are made with other control techniques, including distributed surface roughness and compliant walls.

MSC:
76E15 Absolute and convective instability and stability in hydrodynamic stability
76E07 Rotation in hydrodynamic stability
76D55 Flow control and optimization for incompressible viscous fluids
76D10 Boundary-layer theory, separation and reattachment, higher-order effects
76M99 Basic methods in fluid mechanics

Keywords: boundary layer control; absolute instability; convective instability; Coriolis instability; Chebyshev-tau method; Floquet theory

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References:

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Page 1